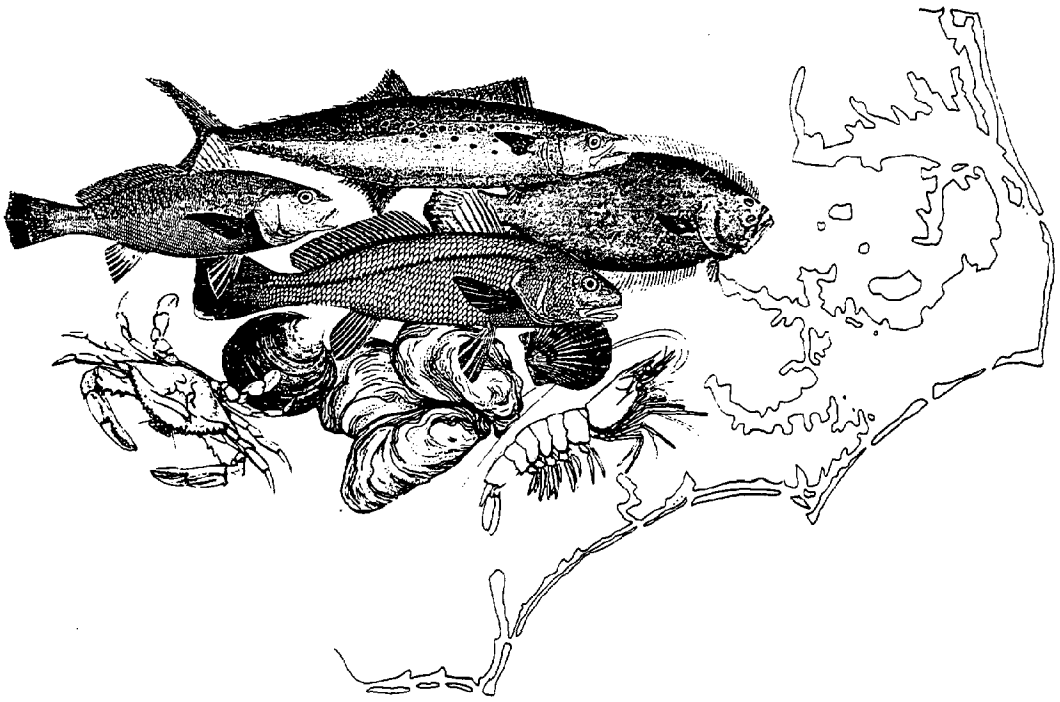
AMERICAN SHAD MIGRATION STUDY



North Carolina Department of Environment,
Health, and Natural Resources

Division of Marine Fisheries
Morehead City, NC 28557

February 1990

AMERICAN SHAD MIGRATION STUDY

by

Jerry A. Parker

North Carolina Department of Environment, Health,
and Natural Resources

Division of Marine Fisheries
Morehead City, NC 28557

Project AFC-35-1

Completion Report

October 1988 - September 1989

February 1990

Funding for this project was provided, in part, by the U.S. Department of Commerce, National Marine Fisheries Service, under PL 89-304, (as amended), Project AFC-35.

TABLE OF CONTENTS

ABSTRACT

A tagging study of American shad (Alosa sapidissima) utilizing 5 1/2 inch mesh gill nets was conducted in the nearshore waters of southeastern North Carolina. The purpose was to determine spawning migrational patterns of American shad. A total of 220 shad was captured between 24 January and 14 April 1989. Of those, 203 were tagged with Floy FT-1 dart tags. Returned tag total was 41 with all but one return collected south of the tagging site. The majority of the tags (30) was recaptured in the Cape Fear and Northeast Cape Fear rivers of North Carolina. South Carolina accounted for 10 returned tags and Georgia had one returned tag. Catch-per-unit-effort (CPUE) was calculated from total catch divided by square-yard-hours of net fished. Daily CPUE's ranged from 0 to 0.0125. Total soak time of the gill nets was over 137 hours with tagging effort taking place on 38 different dates for an average of approximately 3.6 hours of soak time per tagging effort. Findings from the study suggest that there is a viable shad fishery resource in the nearshore ocean waters off North Carolina and that those shad exhibit a pronounced southerly migrational pattern. Hence, the study reasonably confirms that the southeastern North Carolina ocean fishery for shad is to some degree intercepting South Carolina's and Georgia's stocks.

INTRODUCTION

The American shad (Alosa sapidissima (Wilson)) fishery was once the most valuable fishery in North Carolina (Alexander 1905). In 1897, American shad landings were almost 9 million pounds, the highest ever recorded for the state (Townsend 1900). Bowers (1913) reported that North Carolina led all other South Atlantic states with almost 1.3 million fish in 1910. North Carolina landings of American shad have precipitously declined since the early 1900s with overfishing, construction of dams, and pollution generally regarded as the major factors. Johnson (1938) reported that the decline in landings may have also been a result of a decrease in demand for shad from the late 1800s to the 1930s. Despite such obstacles, the American shad fishery is still significant to commercial and recreational fishermen in North Carolina with commericial landings during 1985-1988 of over 1.25 million pounds of shad with a value of over $740,000 (North Carolina Division of Marine Fisheries (DMF) data).

American shad are the largest clupeid in the United States. They are anadromous and reported to range from St. Lawrence River, Canada to St. John's River, Florida on the western Atlantic coast (Nichols and Massmann 1962). Adult American shad migrate to inland spawning grounds throughout its range along the Atlantic coast. Massmann (1952) reported that spawning invariably takes place in fresh water. Juvenile shad spend their first summer in the river in which they were spawned and then migrate downstream to the sea in the fall (McDonald 1884, Smith 1896, Smith 1899, Leggett and Whitney 1972), where they remain until reaching sexual maturity (LaPointe 1958, Neaves and Depres 1979). Sexual maturity is reached in males in 3 to 4 years and in females in 4 to 5 years. Studies by Leggett (1972) showed that shad in the Connecticut River spend 40 to 100 days in fresh water during spawning migrations. Cornell (1955) reported shad to remain in North Carolina waters for a few weeks during that period.

Shad exhibit a pronounced latitudinal cline in postspawning survival (Glebe and Leggett 1981, Carscadden and Leggett 1975). Some authors (Leggett 1972, Sykes and Talbot 1959, Chittenden 1975) report North Carolina to be the geographical boundary between semelparous (spawning once) and iteroparous (repeat spawning) populations of shad with populations south of North Carolina being semelparous and populations north of North Carolina being strongly iteroparous. The incidence of repeat spawning enumerated from scale readings

was 0% in St. John's River, Florida, compared with 3% for the Neuse River in North Carolina, 27% for the James River, Virginia, 38% for the Connecticut River, Connecticut, 72% for the St. John River, New Brunswick (Leggett and Carscadden 1978) and 85% for the Annapolis River, Nova Scotia (Melvin et al. 1985). Glebe and Leggett (1981) attributed the differences in spawning characteristics to the higher amount of energy expended by shad to reach southerly spawning grounds.

The North Carolina commercial fisheries for American shad have traditionally been located in estuaries and inland rivers. Likewise, most studies on American shad in North Carolina have been conducted in inshore waters. Holland and Yelverton (1973) conducted the most recent and thorough study on American shad distribution in the offshore waters of North Carolina. Their capture data suggested that adult American shad were migrating to their spawning grounds as late as March in 1971. Tagging experiments during the study provided no information on migrational patterns because of no reported tag returns.

In 1985-86, a tagging program involving American shad was conducted in nearshore South Carolina ocean waters (G. Ulrich, pers. comm.). The purpose was to monitor shad stocks and gather information on migrational patterns. Results of the study revealed that all but one of the recaptured tagged fish were caught in rivers south of the tagging sites, thus suggesting a southern migrational pattern for shad in South Carolina's nearshore ocean waters. This finding led to speculation that the developing North Carolina ocean fishery for shad may be taking South Carolina stocks. Ocean fishing for shad is discouraged by the Atlantic States Marine Fisheries Commission (ASMFC) fishery management plan which encourages each state to fish on its own stocks in or near natal rivers.

The purpose of this study was to determine the migration patterns of American shad in the nearshore ocean waters of sourtheastern North Carolina and to ascertain if North Carolina's developing ocean gill net fishery for American shad may be intercepting South Carolina's spawning stock.

METHODS AND MATERIALS

Sampling sites were determined by accessibility, weather conditions, fish availability, and recommendations of local shad fishermen. Two one-hundred yard drift gill nets were tied lengthwise. Mesh size of the nets was 5 1/2

inch stretched. The nets were fished approximately every half hour or in incidences of high catch, as often as possible. Initially, the two nets consisted of one 50 mesh deep net tied to one 35 mesh deep net, so as to ascertain which net depth was more efficient for shad capture. Since it was noted that initially all shad were captured within the lower meshes of the 50 mesh depth net, use of the 35 mesh depth net was discontinued after 2 February 1989 in favor of two 50 mesh depth nets. Nets were also left overnight on 2 February 1989, and five shad were captured along with an abundance of menhaden (Brevoortia tyrannus) and spiny dogfish (Squalus acanthias). The nets were severely entangled and the shad were either dead or not suitable for tagging. For that reason, overnight sampling was discontinued.

All captured shad were placed in an oval one hundred and fifteen gallon holding tank filled with ambient sea water where they remained until completion of that particular net fishing cycle. They were then transported to an area at least one thousand yards and directly offshore from the drift nets. As quickly as possible, each shad deemed suitable was measured (fork length, mm), tagged, and released. Also, scales from the left side of the fish posterior to the pectorals were removed and saved for age determination.

Tags and Tagging Method

Floy FT-1 dart tags were chosen and utilized for the study based on their success in previous studies (Eames and Hind 1983, Martin et al 1986, and G. Ulrich pers. comm.). Tags were orange-colored, individually numbered and printed with the agency name, return address, and reward notification. Tags were inserted with a canula on the left side immediately below the dorsal fin. Cash rewards of two dollars were offered for returned tags and a drawing with two $100 prizes was planned to further enhance tag returns.

Desired tag return information included tag number, name and address of fisherman, place caught (water body and nearest landmark), date of capture, gear used in capture and length of fish. Posters advertising the study were placed at local fish markets, boat landings, and other pertinent locations. They were also distributed to other Atlantic states marine fisheries agencies for distribution in their respective states.

Recorded Data

Data from captured shad included fork length (mm), location, and date. Data monitored and recorded from tagging sites included date, location,

surface and bottom temperatures (^{o} C) and salinities (ppt), water depth, wind speed and direction, gear parameters, and soak time for the net. Pre-tagging mortality of shad was noted, as well as all incidental catches.

Scale Samples

Scales from the left side of the shad posterior to the pectoral fin were removed and saved in individually numbered envelopes. Scale removal simply involved scraping a knife against the fish from rear to front to obtain approximately ten to twenty scales. Scales were used to determine age and spawning characteristics of shad as described by Judy (1961). Scales were cleaned with a 5% NaOH solution and examined on a microfiche reader. At least eight scales from each shad were examined. Of those, it was required that readings from at least five scales corresponded. Spawning and ageing data from shad yielding less than eight quality scales or less than five corresponding readings were not included in analyses. Also, there were at least two separate readings of scales from each shad from which only the mutual results were retained for analyses.

RESULTS

A total of 220 shad was captured and measured between 24 January and 14 April 1989. Of those, 203 were considered sufficiently healthy and were tagged. Scales were taken from all captured shad.

Tagging Sites

Seven different nearshore ocean sites were chosen for shad fishing (Figure 1).

1) Wrightsville Beach
2) Masonboro Island
3) Carolina Beach
4) Corncake Inlet
5) Baldhead Island
6) Yaupon Beach
7) Little River

The number and percent of shad captured and/or tagged for each site are shown in Table 1.

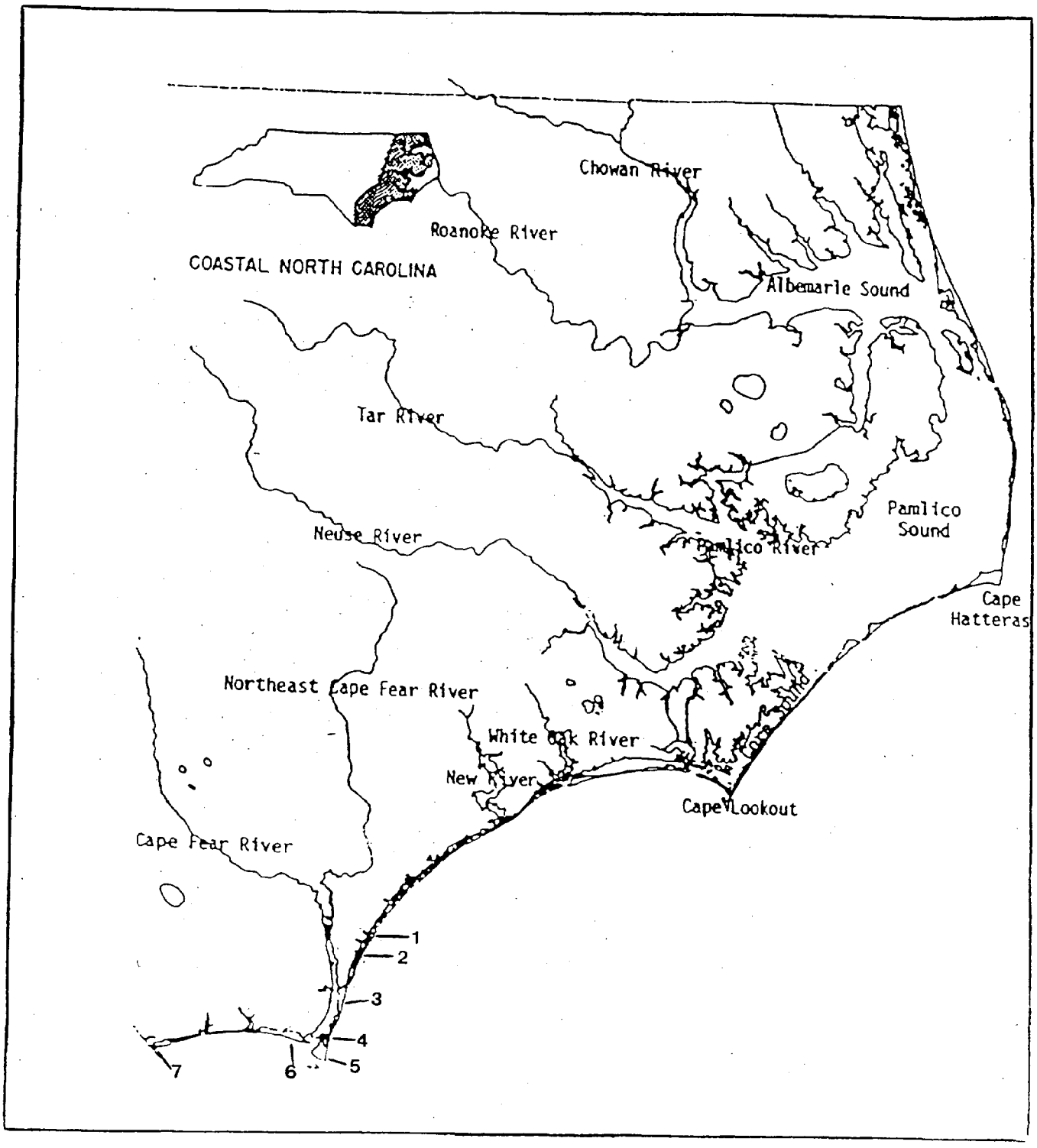


Figure 1. Tagging sites of American shad captured in the nearshore ocean waters off southeastern North Carolina, January-April, 1989. (1. Wrightsville Beach, 2. Masonboro Island, 3. Carolina Beach, 4. Corncake Inlet, 5. Baldhead Island, 6. Yaupon Beach, 7. Little River).

Table 1. Number and percent of American shad captured for each fishing area in the nearshore Atlantic ocean off southeastern North Carolina, January - April 1989.

Area	Total catch	Percent
Wrightsville Beach	200	90.9
Masonboro Island	2	0.9
Carolina Beach	0	0
Corncake Inlet	8	3.6
Baldhead Island	2	0.9
Yaupon Beach	8	3.6
Little River	0	0

Catch-Per-Unit-Effort

All shad were captured in the 50 mesh deep net. Based on visual observations, most appeared to have been trapped near or at the bottom of the net. There were fifteen incidental species captured during the study. Table 2 lists incidental species by site. Fishing effort was measured in "square-yard-hours" of net fished, which was calculated from net depth times net length times number of hours fished. Catch-per-unit effort (CPUE) was calculated from total catch divided by square-yard-hours of net fished. Daily CPUE's ranged from zero on several dates to 0.0125 on 31 March 1989 (Table 3). The Wrightsville Beach site exhibited the highest CPUE, as well as total effort and total catch (Table 4). Two sites, Carolina Beach and Little River, showed zero CPUE, which may have been due to the small amount of effort (square-yds-hrs fished) each area received.

All shad were captured during the morning hours with, the possible exception of the overnight sampling effort. This phenomenon was maintained even during days of high catches.

Age and Length Composition

Based on scale readings, the age composition of the shad was 15.6% four-year-olds, 76.6% five-year-olds and 7.8% six-year-olds (Table 5). There was only one repeat spawner. It measured 520 mm and was determined to be a 6 year-old-fish. Size ranged from 422 mm to 529 mm (Figure 2), with an average length of 484.9 mm. Mean forklength (mm) and length ranges by age group are shown in Table 6. Table 7 shows numbers and percentages of shad per eleven different size ranges.

Tag Return Data

Of the total number (203) of fish tagged, forty-one were recaptured. Of those, thirty (71%) were recaptured in the Cape Fear and Northeast Cape Fear rivers of North Carolina. Both rivers are near the tagging area and have historical gill net fisheries for American shad. South Carolina rivers accounted for ten (27%) returned tags, and Georgia had one (2%) return (Figure 3). Average distance traveled was 89 miles, with the furthest point being 222 miles (Savannah River, Georgia, Table 8). All shad were recaptured south of the tagging site with the exception of one which was recaptured in Croatan Sound, NC, 195 miles north of its tagging site.

Table 2. Incidental species captured in gill nets by site in the nearshore Atlantic ocean areas of southeastern North Carolina, January-April, 1989.

Site	Scientific name	Common name
Wrightsville Beach	Alopias vulpinus	Thresher shark
	Squalus acanthias	Spiny dogfish
	Rhinoptera bonasus	Cownose ray
	Acipenser oxyrhynchus	Atlantic sturgeon
	Brevoortia tyrannus	Atlantic menhaden
	Pomatomus saltatrix	Bluefish
	Archosargus probatocephalus	Sheepshead
	Euthynnus alletteratus	Little tunny
	Sarda sarda	Atlantic bonito
	Peprilus triacanthus	Butterfish
	Macrocoeloma trispinosum	Decorator crab
Masonboro Island	No incidental catch	
Carolina Beach	Brevoortia tyrannus	Atlantic menhaden
Corncake Inlet	Brevoortia tyrannus	Atlantic menhaden
	Squalus acanthias	Spiny dogfish
Baldhead Island	Brevoortia tyrannus	Atlantic menhaden
Yaupon Beach	Squalus acanthias	Spiny dogfish
	Raja eglanteria	Clearnose skate
	Brevoortia tyrannus	Atlantic menhaden
	Cynoscion regalis	Weakfish
	Libinia emarginata	Spider crab
	Callinectes sapidus	Blue crab
Little River	Brevoortia tyrannus	Atlantic menhaden

Table 3. Comparisons of daily catch, area, effort and catch-per-unit-effort (CPUE) for American shad in the nearshore ocean area off southeastern North Carolina, January-April, 1989.

Area	Date	Square yards of net fished	Total catch (number)	CPUE	Square yard hours needed to catch one shad
Yaupon Beach	1-24	1,940	0	-	-
Yaupon Beach	1-26	2,280	0	-	-
Baldhead Island	1-26	1,600	0	-	-
Yaupon Beach	2-2	28,500*	6	0.0002	4750.00
Yaupon Beach	2- 7	2,280	0	-	-
Yaupon Beach	2- 9	1,140	0	-	-
Yaupon Beach	2-15	1,140	0	-	-
Carolina Beach	2-16	1,140	0	-	-
Corncake Inlet	2-16	3,705	3	0.0008	1235.00
Corncake Inlet	2-20	2,280	4	0.0018	570.00
Wrightsville Beach	2-21	2,280	3	0.0013	760.00
Masonboro Island	2-22	2,280	0	-	-
Wrightsville Beach	2-27	3,990	2	0.0005	1995.00
Yaupon Beach	3- 3	6,270	2	0.0003	3135.00
Yaupon Beach	3- 6	1,140	0	-	-
Baldhead Island	3- 6	1,710	2	0.0001	855.00
Wrightsville Beach	3- 7	1,140	5	0.0044	228.00
Wrightsville Beach	3-14	3,420	0	-	-
Masonboro Island	3-14	3,420	2	0.0006	1710.00
Wrightsville Beach	3-15	6,840	2	0.0003	3420.00
Corncake Inlet	3-16	3,420	1	0.0003	3420.00
Wrightsville Beach	3-17	4,560	3	0.0007	1520.00
Wrightsville Beach	3-21	2,280	14	0.0061	162.85
Wrightsville Beach	3-22	2,280	0	-	-
Wrightsville Beach	3-27	2,280	0	-	-
Wrightsville Beach	3-28	2,280	6	0.0026	380.00
Wrightsville Beach	3-29	5,130	10	0.0019	513.00
Wrightsville Beach	3-30	4,560	3	0.0007	1520.00
Wrightsville Beach	3-31	3,990	50	0.0125	79.80
Wrightsville Beach	4- 1	3,990	26	0.0065	153.46
Wrightsville Beach	4- 3	5,130	26	0.0051	197.31
Wrightsville Beach	4- 4	4,275	20	0.0047	213.75
Wrightsville Beach	4- 5	2,280	1	0.0004	2280.00
Wrightsville Beach	4- 6	1,140	0	-	-
Wrightsville Beach	4- 7	1,140	0	-	-
Wrightsville Beach	4-10	3,420	0	-	-
Wrightsville Beach	4-12	3,420	15	0.0044	228.00
Wrightsville Beach	4-13	2,850	14	0.0050	203.57
Wrightsville Beach	4-14	2,850	0	-	-
Wrightsville Beach	4-17	1,516	0	-	-
Wrightsville Beach	4-18	1,710	0	-	-
Little River Inlet	4-21	3,420	0	-	-

* 24 hour sampling effort

Table 4. Site comparisons of total catch, effort, and catch-per-unit-effort (CPUE) for American shad captured in the nearshore ocean area off southeastern North Carolina, January-April, 1989.

Area	Square yard hours of net fished	Total catch (number)	CPUE	Square yard hours needed to catch one shad
Wrightsville Beach	78,751	200	0.0025	393.76
Masonboro Island	5,700	2	0.0004	2850.00
Carolina Beach	1,140	-	-	-
Corncake Inlet	9.405	8	0.0009	1175.63
Baldhead Island	3,310	2	0.0006	1655.00
Yaupon Beach	44,690	8	0.0002	5586.25
Little River	3,420	-	-	-

Table 5. Number and percent of shad captured by age in the nearshore ocean area off southeastern North Carolina, January-April, 1989.

Age (yr)	Number	Percent
IV	32	15.6
V	157	76.6
VI	16	7.8

Table 6. Mean forklength (mm) and length ranges (mm) by age group for American shad from the nearshore ocean area off southeastern North Carolina, January-April 1989.

Age group	Number	Mean	±	S.D.	Range Min.	Range Max.
IV	32	450.7		14.3	442	470
V	157	487.8		15.6	448	520
VI	16	516.2		13.7	488	529

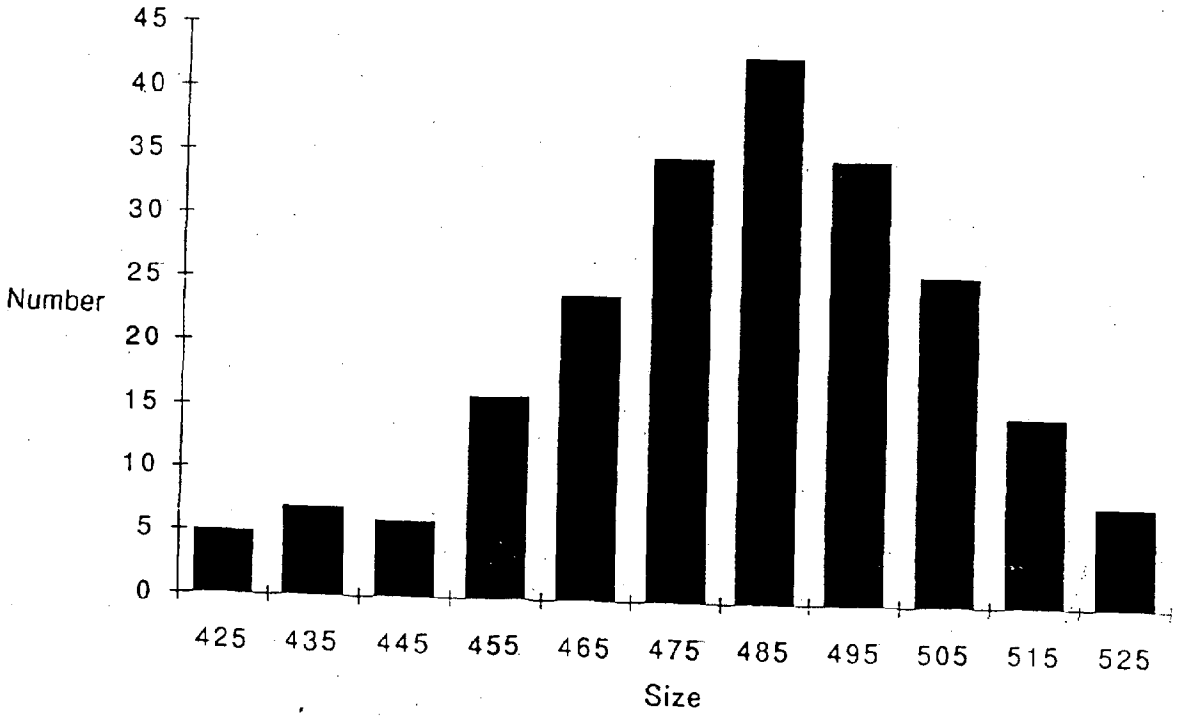


Figure 2. Number of American shad captured by size range from the nearshore ocean area off southeastern North Carolina, January-April, 1989.

1. Croatan Sound
2. Northeast Cape Fear River
3. Cape Fear River
4. Brunswick River
5. Carolina Beach
6. Corncake Inlet
7. Baldhead Island
8. Pee Dee River
9. Winyah Bay
10. Edisto River
11. Savannah River

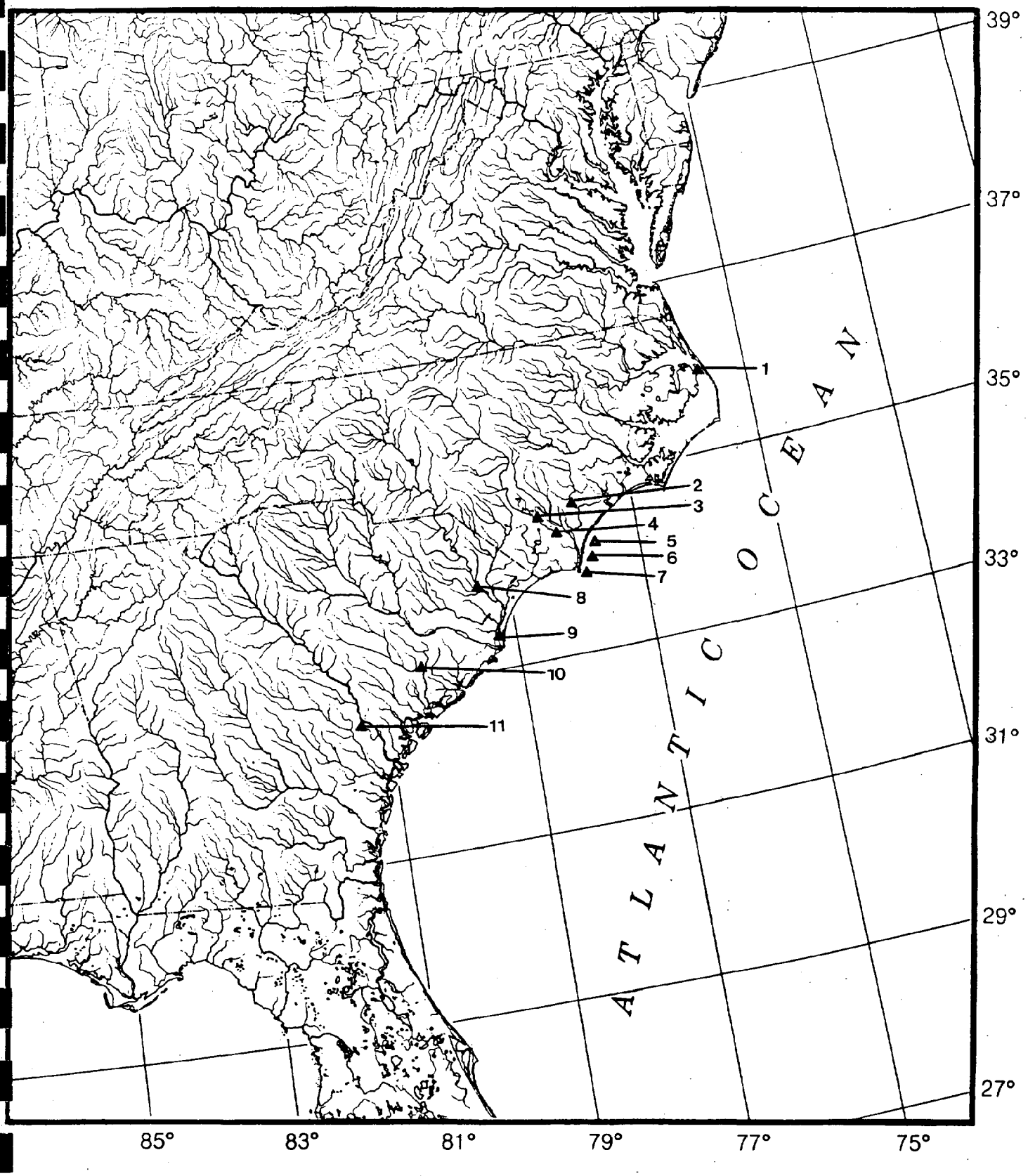


Figure 3. Recapture sites of American shad captured in the nearshore waters off southeastern North Carolina, January-April, 1989.

Table 7. Number and percent of shad captured by size range from the nearshore ocean area off southeastern North Carolina, January - April, 1989.

Size range (mm, FL)	Number	Percent
421-430	5	2.3
431-440	7	3.2
441-450	6	2.7
451-460	16	7.3
461-470	24	10.9
471-480	35	15.9
481-490	43	19.6
491-500	35	15.9
501-510	26	11.8
511-520	15	6.8
521-530	8	3.6
Total	220	100.00

Table 8. Capture and recapture locations, distance traveled and days at large for American shad tagged and released in the nearshore ocean off southeastern North Carolina, January-April, 1989.

Capture location	Recapture location	Distance from site (miles)	Days at large
Wrightsville Beach	Savannah River, GA	222	14
"	Pee Dee River, SC	120	25
Yaupon Beach	Brunswick River, NC	26	15
"	Cape Fear River, NC	34	43
Masonboro Island	Winyah Bay, SC	97	8
Corncake Inlet	Cape Fear River, NC	82	20
Wrightsville Beach	Winyah Bay, SC	92	5
"	Cape Fear River, NC	105	6
"	Edisto River, SC	185	8
"	Cape Fear River, NC	97	6
"	Cape Fear River, NC	97	8
"	Pee Dee River, SC	120	9
"	Cape Fear River, NC	35	17
"	Cape Fear River, NC	99	14
"	Cape Fear River, NC	78	9
"	-	-	-
"	Edisto River, SC	185	19
"	Pee Dee River, SC	130	7
"	NE Cape Fear River, NC	86	6
"	Carolina Beach, NC	13	3
"	Pee Dee River, SC	120	9
"	Corncake Inlet, NC	23	3
"	NE Cape Fear River, NC	85	11
"	Cape Fear River, NC	84	6
"	Pee Dee River, SC	130	7
"	Carolina Beach, NC	13	2
"	Cape Fear River, NC	97	20
"	Pee Dee River, SC	147	19
"	Baldhead Island, NC	25	1
"	NE Cape Fear River, NC	85	5
"	NE Cape Fear River, NC	98	33
"	Croatan Sound, NC	195	16
"	Cape Fear River, NC	58	5
"	Corncake Inlet, NC	23	3
"	Corncake Inlet, NC	23	1
"	Corncake Inlet, NC	23	1
"	NE Cape Fear River, NC	75	16
"	Cape Fear River, NC	105	13
"	NE Cape Fear River, NC	88	8
"	Brunswick River, NC	58	9
"	Cape Fear River, NC	100	8

Average number of days at large was 11 days with a range of 1 to 43 days. The shad at large the greatest number of days (43) was captured at Yaupon Beach, NC and recaptured in Cape Fear River, NC It traveled a distance of only 34 miles.

Environmental Parameters

Temperatures at which shad were captured ranged from 8.0° C to 14.9° C, with the maximum number of shad caught at 13° C. Salinities during the sampling period ranged from 32.0 to 36.0 parts per thousand (Table 9). Water depth at sampling sites ranged from 4.5 meters to 9.0 meters (Table 10). Wind speed and direction were also monitored and recorded and are shown in Table 10.

DISCUSSION AND CONCLUSIONS

Age and size of shad captured during the study were greatly influenced by gear type and mesh size. Gill nets have been reported to bias the length range and sex ratios of adult shad (Weinrich et al. 1988). Therefore, it would be impractical to determine average year-class size or age based on information obtained from the study. The 5 1/2 inch stretched mesh was selected for capture because it was the preferred mesh size of commercial shad fishermen who were expected to be the primary source of recapture data. A more accurate age and size composition probably could have been obtained by utilizing a range of mesh sizes. However, the recapture data would have been skewed due to the commercial fishermen's preference for the larger roe shad, thus, defeating the primary purpose of the study.

An advantage of selectivity of mesh sizes is that all the recaptures were females, and presumably all or most of the tagged shad were female. (Positive sex of shad could not be determined during tagging due to time and health restraints and difficulty of visual sex identification). Thus, information from the study probably provides information on the female population and their migration patterns.

Shad were captured throughout the entire range of temperatures and salinities. Based on the relatively small fluctuations in temperature (8.0 ° C-14.9° C) and salinity (32.0 ppt-36.0 ppt), no conclusions could be drawn to ascertain the upper and/or lower limits required for shad during migrations. The small fluctuations in water depth between sampling sites was due to an

Table 9. Water temperature, salinity, and number of shad captured, by date of capture for each tagging site in the nearshore ocean area off southeastern North Carolina, January-April 1989

Site	Date	Temperature (°C)		Salinity (ppt)		Number of shad captured
		Surface	Bottom	Surface	Bottom	
Yaupon Beach	1-24-89	10.3	9.9	33.9	35.7	0
"	1-26-89	11.9	10.7	35.2	35.6	0
"	2- 2-89	13.0	12.9	32.0	35.4	6
"	2- 7-89	13.3	12.1	32.8	34.1	0
"	2- 9-89	11.5	11.6	33.8	34.7	0
"	2-15-89	13.5	12.7	33.2	33.0	0
"	3- 3-89	10.8	10.3	35.5	36.0	2
"	3- 6-89	14.0	11.0	33.2	33.1	0
Baldhead Island	1-26-89	11.8	10.7	35.2	35.6	1
"	3- 6-89	12.0	11.0	33.0	33.1	2
Carolina Beach	2-16-89	12.2	11.8	34.4	34.2	0
Corncake Inlet	2-16-89	12.1	11.7	34.3	34.6	0
"	2-20-89	12.0	11.6	34.7	35.1	4
"	3-16-89	11.3	10.7	34.3	35.0	1
Masonboro Island	2-22-89	11.1	11.1	35.5	35.6	0
"	3-14-89	9.2	8.0	35.1	34.9	2
Wrightsville Beach	2-21-89	10.7	10.7	35.0	35.0	3
"	2-27-89	10.1	10.3	34.8	35.2	2
"	3- 7-89	10.8	10.8	35.1	35.4	5
"	3-14-89	8.7	8.8	35.2	35.2	0
"	3-15-89	9.6	9.2	35.2	35.1	2
"	3-17-89	10.1	10.1	35.1	35.4	3
"	3-21-89	12.0	12.0	34.3	34.5	14
"	3-22-89	12.5	12.6	34.3	34.2	0
"	3-27-89	13.6	13.2	33.7	33.6	0
"	3-28-89	14.9	14.7	37.8	31.2	6
"	3-29-89	12.8	12.8	34.1	34.2	10
"	3-30-89	12.9	12.4	34.3	33.9	3
"	3-31-89	13.0	13.0	33.9	34.1	50
"	4- 1-89	13.3	13.3	34.1	34.0	26
"	4- 3-89	13.4	13.4	34.0	34.0	26
"	4- 4-89	13.7	13.7	34.0	33.9	20
"	4- 5-89	13.8	13.8	33.9	34.2	1
"	4- 6-89	13.9	13.9	33.9	33.9	0
"	4- 7-89	14.2	14.2	34.2	34.2	0
"	4-10-89	14.2	14.2	34.3.	34.2	0
"	4-12-89	12.6	12.5	33.7	33.6	15
"	4-13-89	12.6	12.6	33.6	33.6	14

Table 9. (Continued).

Site	Date	Temperature (°C) Surface	Temperature (°C) Bottom	Salinity (ppt) Surface	Salinity (ppt) Bottom	Number of shad captured
Wrightsville Beach	4-14-89	13.3	13.3	33.8	33.8	0
"	4-17-89	13.6	13.4	33.8	33.8	0
"	4-18-89	14.1	14.1	33.8	34.3	0
Little River	4-21-89	14.3	14.1	33.4	33.8	0

Table 10. Wind direction, wind speed, depth, and number of shad captured, by date of capture for each tagging site in the nearshore ocean area off southeastern North Carolina, January-April, 1989.

Site	Date	Wind direction	Wind speed (mph)	Water depth (meters)	Number of shad captured
Yaupon Beach	1-24-89	NE	10	9	0
"	1-26-89	NE	15	9	0
"	2- 2-89	NE	10	7	6
"	2- 7-89	S	5	6.5	0
"	2- 9-89	N	10	7	0
"	2-15-89	SW	5	6	0
"	3- 3-89	NE	15	4	2
"	3- 6-89	NE	10	4	0
Baldhead Island	1-26-89	NE	15	9	1
"	3- 6-89	NE	10	5	2
Carolina Beach	2-16-89	SW	5	7	0
Corncake Inlet	2-16-89	SW	5	4.5	0
"	2-20-89	S	5	4.5	4
"	3-16-89	NE	25	5	1
Masonboro Island	2-22-89	S	5	5	0
"	3-14-89	SE	15	6	2
Wrightsville Beach	2-21-89	S	20	6	3
"	2-27-89	SW	5	6	2
"	3- 7-89	NE	25	5	5
"	3-14-89	SE	15	6	0
"	3-15-89	SW	20	4	2
"	3-17-89	NE	15	5	3
"	3-21-89	SE	20	6	14
"	3-22-89	NE	25	6	0
"	3-27-89	NE	5	6	0
"	3-28-89	SE	20	6	6
"	3-29-89	SW	15	7	10
"	3-30-89	SW	20	6	3
"	3-31-89	SW	10	7	50
"	4- 1-89	NE	10	7	26
"	4- 3-89	SE	10	7	26
"	4- 4-89	SW	15	7	20
"	4- 5-89	SW	20	7	1
"	4- 6-89	SW	20	7	0
"	4- 7-89	NE	15	7	0
"	4-10-89	NE	5	7	0
"	4-12-89	NE	20	7	15
"	4-13-89	NE	15	7	14

Table 10. (Continued)

Site	Date	Wind direction	Wind speed (mph)	Water depth (meters)	Number of shad captured
Wrightsville Beach	4-14-89	NE	10	7	0
"	4-17-89	NE	10	7	0
"	4-18-89	SW	15	7	0
Little River Inlet	4-21-89	SW	15	9	0

intentional effort by the samplers to fish the nets at a depth at which it was felt they covered or nearly covered the entire water column. Other environmental parameters, such as, wind speed and wind direction did not appear to have a significant bearing on shad capture. However, most commercial shad fishermen strongly suggested a northeast wind and high wind speeds (>15 mph) as the most favorable wind direction and speed for ocean shad capture.

Analyses of catch and tagging data suggest that there is a viable shad fishery resource in the near shore ocean waters off North Carolina and that those shad exhibit a pronounced southerly migrational pattern. Over 99% of all tag returns were reported captured south of the tagging site, with approximately 24% percent recaptured in South Carolina and Georgia. Although based on only one year of data and therefore subject to bias introduced from any number of abiotic and biotic factors, the study reasonably confirms that the southeastern North Carolina ocean fishery for shad is to some degree intercepting South Carolina's stocks. If North Carolina is to totally comply with the ASMFC policy of fishing entirely on its own stock, then some regulations on ocean shad fishing may be necessary. Points to consider when determining regulations should include information on number of ocean shad fishing boats, number of fish and pounds landed yearly, potential growth of the fishery, peak fishing periods, type of gear and selectivity of gear in reference to size, age and sex of fish captured.

ACKNOWLEDGEMENTS

I wish to acknowledge the efforts of many Division of Marine Fisheries personnel, without whom this project would not have been possible; especially, Federal Aid Coordinator Maury Wolff, Chief of Research Section Mike Street, Biologist John Schoolfield and Technicians Jack Hunter and Otto Rutten. Special thanks are also given to the United States Department of Commerce through the National Marine Fisheries Service for providing partial funding for the project and to the commercial shad fishermen whose cooperation was sincerely appreciated.

LITERATURE CITED

Alexander, A.B.
1905. Statistics of the fisheries of the South Atlantic States, 1902. U.S. Commissioner of Fish and Fisheries, Report for 1903, p. 343-410.

Bowers, G.M.
1913. Shad Fisheries. U.S. Commissioner of Fisheries, Report for 1911. p.35-37.

Carscadden, J.E., and W.C. Leggett.
1975. Life history variation in populations of American shad, Alosa sapidissima (Wilson), spawning in tributaries of the St. John River, New Brunswick. J. Fish. Biol. 7:595-609.

Chittenden, M.E., Jr.
1975. Dynamics of American shad, Alosa sapidissima, in the Delaware River, Fish. Bull., 74: 343-352.

Cornell, J.H.
1955. The White shad. Wildlife in North Carolina. 19(6): 14-17.

Eames, M.J., and M.K. Hind.
1983. An evaluation of four tags suitable for marking juvenile chinook salmon. Trans. Amer. Fish. Soc. 112: 464-468.

Glebe, B.D., and W. C. Leggett.
1981. Latitudinal differences in energy allocation and use during the fresh water migrations of American shad (Alosa sapidissima) and their life history consequences. Can. J. Fish. Aquat. Sci. 38: 806-820.

Holland, B.F., Jr., and G. Frank Yelverton.
1973. Distribution and biological studies of anadromous fishes offshore North Carolina. N.C. Dept. of Natural and Economic Resources, Div. of Commercial and Sports Fisheries. Special Scientific Report No. 24, 132p.

Johnson, F.F.
1938. Marketing of shad on the Atlantic coast. U.S. Bureau of Fisheries. Investigational Report, No. 38, 44p.

Judy, M. H.
1961. Validity of age determinations from scales of marked American shad. U.S. Fish Wildl. Serv. Fish. Bull. 61: 161-170.

LaPointe, D.F.
1958. Age and growth of the American shad from three Atlantic coast rivers. Trans. Amer. Fish. Soc. 87: 139-150.

Leggett, W.C.
1972. Weight loss in American shad (Alosa sapidissima) during the fresh water migration. Trans. Amer. Fish. Soc. 10(13): 549-552.

Leggett, W.C., and J.E. Carscadden.
1978. Latitudinal variation in reproductive characteristics of American shad (Alosa sapidissima): evidence for population specific life history strategies in fish. J. Fish. Res. Board Can. 35:1469-1478.

Leggett, W.C., and R.R. Whitney.
1972. Water temperature and the migrations of American shad. Fish. Bull. 70(3) 659-670.

Marcy, B.C., Jr.
1969. Age determinations from scales of Alosa pseudoharengus (Wilson) and Alosa aestivalis (Mitchill) in Connecticut waters. Trans. Amer. Fish. Soc. 98(4): 622-630.

Massmann, W.H.
1952. Characteristics of spawning areas of shad, Alosa sapidissima (Wilson) in some Virginia streams. Trans. Amer. Fish. Soc. 81: 78-93.

McDonald, M.
1884. The shad, Clupea sapidissima, p. 594-607. In: G.B. Goode and Associates, the fisheries and fishery industries of the United States. Section I. Natural history of useful aquatic animals, p. 594-607. U.S. 47th Congr. 1st Sess. Senate Misc. Doc. 124.

Melvin, G.D., M.J. Dadswell, and J.D. Martin.
1985. Fidelity of American shad, Alosa sapidissima (Clupeidae), to its river of previous spawning. Can. J. Fish. Aquat. Sci. 43(3): 640-646.

Neaves, R.J., and L. Depres.
1979. The oceanic migration of American shad, Alosa sapidissima along the Atlantic coast. Fish. Bull. 77(1): 199-212.

Nichols, P.R., and W.H. Massmann.
1962. Abundance, age and fecundity of shad, York River, Va. 1953-59. Fish. Bull. 63(1): 179-187.

Rothschild, B.J.
1963. A critique of the scale method for determining the ages of the alewife, Alosa pseudoharengus (Wilson). Trans. Amer. Fish. Soc. 92(4): 409-413.

Smith, H.M.
1896. A review of the history and results of the attempts to acclimatize fish and other water animals in the Pacific states. Bull. U.S. Fish Comm. 15: 379-472.

Smith, H.M.
1899. Studies of young shad in Potomac River, In: Report on the inquiry respecting food-fishes and the fishing grounds. p. cxxxviii-cxxxix. U.S. Comm. Fish., Part 24, Rep. Comm. 1898.

Sykes, J.E., and G.B. Talbot.
1959. Progress in Atlantic coast shad investigations-migration. Proceedings of the Gulf and Carribbean Fisheries Institute, 11th Annual Session, p. 82-90.

Townsend, C.H.
1900. Statistics of the fisheries of the South Atlantic states. U.S. Commissioner of Fish and Fisheries Report for 1899, pt. 25, p. 171-227.

Weinrich, D.R., N. Butowski, and J.P. Mowrer.
1988. Investigation of anadromous alosids. USFWS Federal Aid Annual Report. 143 p.